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HUNTING AND CURVING PERFORMANCE OF RIGIDIZED ELASTO-CUSHION TRUCKS

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17. Abstract

A field test program was carried out to determine the hunting and curving performance of 100-ton Barber S-2 three-piece trucks rigidized by transoms between the truck side-frames to prevent parallelogramming and equipped with elastomeric shear pads (i.e., a rigidized elasto-cushion truck).

Curving test results in a 5 degree curve with new Heumann profile wheels showed that the angles-of-attack and lateral forces were significantly lower for a rigidized elasto-cushion truck as compared to the conventional Barber S-2 truck.

Hunting tests with service worn wheels showed that the lateral ride of rigidized elasto-cushion trucks was slighly worse than that of conventional trucks. The rigidized elasto-cushion truck, shear pads of 21,000 lbs/in and service worn wheels hunted above 60 mph whereas with conventional car trucks with service worn wheels and C-PEP hunting was intermittent in the speed range 60-65 mph.

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17. Résumé

Un programme d'essais a été lancé pour étudier la stabilité en marche des bogies Barber S-2 à 3 éléments équipant des wagons de 100 tonnes, rigidifiés par une entretoise placée entre les longerons pour empêcher leur déformation dans les courbes et munis de blocs caoutchouc, devenant ainsi des bogies de types "elasto-cushion" rigidifiés.

Les essais d'inscription en courbe (5º) de ces bogies équipés de roues neuves à profil Heumann ont montré une atténuation sensible des angles d'inscription et des forces transversales, comparativement aux valeurs correspondantes d'un bogie standard.

Les essais sur le phénomène de lacet ont montré que la stabilité latérale des bogies ainsi modifiés s'était légèrement détériorée par rapport aux bogies standard. Alors que sur les premiers, équipés de blocs caoutchouc d'une raideur en cisaillement de 21 000 lb/po et de roues à profile d'usure, un phénomène de lacet s'est manifesté au-dessus de 60 mi/h, les bogies standard équipés de blocs C-PEP et de roues à usure caractéristique n'ont montré, eux, qu'un lacet intermittent dans l'intervalle de vitesses entre 60 et 65 mi/h.

18. Mots-clés	19. Diffusion
Lacet, inscription en courbe, bogies standard à 3 éléments, bogies elasto-rigides, blocs caoutchouc, angles d'inscription, forces transversales/ verticales	Le Centre de développement des transports dispose d'un certain nombre d'exemplaires

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EXECUTIVE SUMMARY

Hunting and curving performance tests were carried out in the fall of 1983 to study the behaviour of 100-ton Barber S-2 trucks rigidized by a transom between the truck sideframes to prevent truck parallelogramming. In addition, elastomeric shear pads between the bearing adapter/sideframe pedestal roof were used to allow wheelset steering.

Earlier test work carried out with elastomeric shear pads in a conventional 100-ton Barber S-2 truck had shown the need to rigidize a truck in order to improve curving and stability performance. For test purposes, two carsets of trucks were rigidized, one carset with 1 pin transoms and a second carset with 5 pin transoms. Static parallelogramming tests of the truck sideframes showed that the 1 pin transoms were ineffective in rigidizing the trucks, and that the 5 pin transoms rigidized the trucks. However, the test car trucks with the 5 pin transoms were inadvertently not maintained square when initially rigidized.

Hunting tests showed that the lateral ride of a rigidized elasto cushion trucks was slightly worse than that of the conventional trucks. The rigidized elasto cushion truck with shear pads of 21,000 lb/in and service worn wheels hunted above 60 mph whereas the conventional car trucks with service worn wheels and C-PEP hunted intermittently in the speed range of 60-65 mph. The test car trucks which were not held rigid (i.e. 1 pin transoms, shear pads of 15,000 lb/in shear stiffness and service worn wheels) hunted intermittently at 50 mph.

Curving performance tests were carried out in a 5 degree curve at, above and below the balance speed. Prior to the curving tests stops were welded to the sideframes and transoms of the trucks with the 1 pin transoms to effectively rigidize the trucks. The angles-of-attack and lateral forces were significantly lower for these trucks as compared to the conventional Barber S-2 trucks. Since the trucks with the five pin transoms were not square they were not suitable as indicators of the benefits of a rigidized truck with elastomeric shear pads.

SOMMAIRE

Des essais sur le phénomène de lacet et sur les inscriptions en courbe ont été faits à l'automne de 1983 pour étudier le comportement des bogies Barber S-2 équipant des wagons de 100 tonnes, rigidifiés grâce à une entretoise placée entre les deux longerons et visant à empêcher la déformation du bogie dans les courbes. En outre, des blocs en caoutchouc synthétique ont été placés entre l'adaptateur du roulement et le longeron de manière à donner une flexibilité radiale au bogie.

Les essais antérieurs faits sur un bogie S-2 standard équipé de blocs caoutchouc avaient montré l'intérêt qu'il y aurait à le rigidifier afin d'en relever les caractéristiques de marche en alignement et en courbe. Pour les fins des essais, les bogies de deux wagons ont été rigidifiés par des entretoises fixées par une cheville de chaque côté dans un cas, et par cinq de chaque côté dans l'autre. Des essais statiques de déformation ont montré que l'entretoise à une cheville par côté ne réussissait pas à rigidifier le bogie comme le faisait celle à 5 chevilles; cependant, au moment de mettre celle-ci en place, le bogie n'avait pas été, par mégarde, maintenu d'équerre.

Les essais sur le phénomène de lacet ont montré que la stabilité latérale des bogies ainsi modifiés s'était légèrement détériorée par rapport aux bogies standard. En effet, alors que sur les premiers équipés de blocs caoutchouc d'une raideur en cisaillement de 21 000 lb/po et de roues à profil d'usure un phénomène de lacet s'est manifesté au-dessus de 60 mi/h, les bogies standard, équipés de blocs caoutchouc C-PEP et de roues à usure caractéristique, n'ont montré, eux, qu'un lacet intermittent dans l'intervalle de vitesses entre 60 et 65 mi/h. Quant aux bogies non rigidifiés (c'est-à-dire équipés d'une entretoise à 1 cheville par côté, de blocs caoutchouc à raideur de cisaillement de 15 000 lb/po et de roues à usure caractéristique) ils ont montré un lacet intermittent dès 50 mi/h.

Des essais d'inscription dans une courbe de 5^{0} ont été faits à vitesses égale, supérieure et inférieure à la vitesse d'équilibre. Des butées avaient été au préalable soudées aux longerons et aux entretoise à 1 cheville par côté dans le but de rigidifier les bogies. Il a été constaté que les angles d'inscription et les forces transversales dans le cas de ces bogies s'étaient sensiblement atténués, comparativement aux valeurs correspondantes d'un bogie S-2 standard. Les bogies rigidifiés par l'entretoise à 5 chevilles par côté n'ont pas d'équerre, ils ne peuvent donc servir de référence pour déterminer les avantages du bogie ainsi modifié.

La méthode utilisée pour rigidifier les bogies Barber S-2 destinés aux wagons de 100 tonnes réussit à réduire les angles d'inscription en courbe et les forces transversales, à condition que ces bogies aient été maintenus d'équerre au moment de la modification. Par contre, dans ce cas, les blocs caoutchouc ne font que réduire la souplesse d'action des essieux et la stabilité latérale du bogie.

Rigidizing the conventional 100-ton Barber S-2 truck by means of a transom and utilizing elastomeric shear pads at the bearing adapter/pedestal interface is a viable method of reducing lateral curving forces and angles-of-attack provided the truck is maintained square when initially rigidized. However, introducing elstomeric shear pads in a truck rigidized by means of a transom reduces the restraint on axle lateral and yaw motion and hence truck lateral stability.

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1.0 INTRODUCTION

Previous research conducted by Canadian Pacific on a conventional Barber S-2 100-ton three-piece freight car truck modified by the insertion of elastomeric shear pads at the pedestal roof/bearing adapter interface showed an improvement in curving performance at or above balance speed in comparison to a car with conventional trucks (Reference 1). However, below balance speed the trucks equipped with elastomeric shear pads parallelogrammed during curve negotiation which resulted in an increase in angle-of-attack and lateral forces compared to conventional trucks.

A conventional three-piece freight car truck is characterized by a high interaxle yaw stiffness and low interaxle shear. Introduction of elastomeric shear pads at the pedestal roof bearing adapter interface of a truck while reducing the interaxle yaw stiffness, which improves curving, also reduces the interaxle shear which affects lateral stability of the three-piece truck. This reduced stability of the conventional three-piece truck utilizing shear pads of a 15,000 lb/in shear stiffness was documented in Reference 1.

As a result of earlier test work with elastomeric shear pads applied to a conventional three-piece truck and discussions between Mr. H. List of Railway Engineering Associates, and the Mechanical Department of CP Rail, it was decided to rigidize two carsets of trucks with transoms between the sideframes to prevent parallelogramming. The main purpose of the test was to determine if most of the benefits of radial self-steering trucks could be obtained without the additional weight penalty associated with radial trucks. The Research Department undertook a field test program to determine the curving and stability characteristics of a 100-ton Barber S-2 three-piece truck rigidized by means of a transom and equipped with elastomeric shear pads (ie. a rigidized elasto cushion truck).

This report documents the methodology, observations and test results of the curving performance and stability test program for Barber S-2 rigidized elasto-cushion trucks and reference conventional Barber S-2 three-piece trucks.

2.0 STATIC PARALLELOGRAMMING TESTS ON MODIFIED TRUCKS

Two carsets of 100-ton Barber S-2 trucks were rigidized by using a transom between the sideframes of a truck to prevent truck parallelogramming. One carset of trucks was rigidized by transoms with one pin on each sideframe and the trucks of the second car were rigidized using transoms with five pins on each sideframe (see Figure 1).

Parallelogramming tests were carried out on one truck of each of the two test cars equipped with transoms (1 pin and 5 pin) and elastomeric shear pads at the pedestal roof/bearing adapter interface under a light 100-ton bathtub coal car. Approximately 2,500 lbs. force applied at diagonally opposite corners of the trucks' sideframes was required to parallelogram the wheelsets of the truck rigidized by a transom with one pin. In comparison, the truck with five pin transoms did not parallelogram with a force up to 7,000 lbs.

During assembly, the rigidized trucks with the five pin transoms were inadvertently not held square. Hence, the trucks of this car have a preferential direction of travel while negotiating a curve.

3.0 HUNTING TESTS AND ANALYSIS OF RIGIDIZED ELASTO-CUSHION TRUCKS

3.1 Test Site

Stability tests to a maximum speed of 65 mph were carried out on the Brooks Subdivision east of Calgary between Mileages 160-158. The two mile test zone consisted of tangent track with continuous welded 115 lb/yard rail.

3.2 Test Cars

Four empty 100-ton bathtub coal cars were used as the test cars. Two of the cars were equipped with rigidized elasto cushion trucks. One of the cars with modified trucks (5 pin transoms) was equipped with shear pads of 21,000 lb/in. shear stiffness while the other test car trucks (1 pin transoms) had shear pads of 15,000 lb/in. shear stiffness. Both cars with modified trucks were tested with service worn wheels.

Two similar cars with conventional Barber S-2 100-ton trucks with C-PEP were used as reference cars. One of the reference cars had new Heumann wheels and the second reference car was equipped with service worn wheels.

3.3 Instrumentation

The four test cars were instrumented with accelerometers to determine wheelset lateral acceleration. The accelerometers, on the leading axles of each of the two trucks of the test cars, were mounted laterally at the end of the axles on specially designed bearing endcaps.

Speed of the test cars during each test run was continuously monitored. Acceleration signal data were recorded on an 8-channel Brush Chart Recorder.

3.4 Test Consist

The test consist was made up of one SD40-2 locomotive, four empty 100-ton bathtub coal test cars, Dynamometer Car CP 62 which was used as the instrumentation car and a crew caboose.

3.5 Test Procedure

The test procedure consisted of running the captive test consist in speed increments of 5 mph from 30 to 65 mph. Tests were all run in the same direction with the required test speed being attained prior to the two mile test zone. In the two mile test zone the speed was held relatively constant to record the lateral acceleration signal data.

3.6 Discussion of Test Results

Figures 2 and 3 illustrate the lateral acceleration of a wheelset for the two cars with elasto-cushion trucks and service worn wheels at 50, 60 and 65 mph. The test car with the 1 pin transom trucks commenced intermittent hunting at 50 mph. Above 60 mph both test cars with elasto-cushion trucks (1 pin and 5 pin transoms) were hunting most of the time in the two mile test zone. As can be observed from Figures 2 and 3 a higher lateral acceleration was recorded for the car with the 1 pin transom trucks as compared to that with the 5 pin transoms. The lower speed threshold for intermittent truck hunting and higher lateral acceleration recorded on the car with the 1 pin transom trucks was due to a combination of the truck not being held rigid and elastomeric shear pads of a lower shear stiffness.

Figures 4 and 5 illustrate the lateral acceleration of a wheelset for the two reference cars at similar test speeds over the same section of track. From Figure 4 it can be observed that intermittent truck hunting occurred at 60 mph for the reference car with C-PEP and service worn wheels. Figure 5 illustrates that the second reference car, with new Heumann profile wheels and C-PEP, did not hunt to a maximum test speed of 65 mph.

3.7 Test Results

1. For the car with the five pin transoms intermittent truck hunting was observed at 60 mph.

2. The car with the one pin transoms commenced hunting intermittently at 50 mph.

3. The reference car with C-PEP and service worn wheels commenced hunting intermittently at 60 mph. With new Heumann profile wheels and C-PEP, no hunting was observed on the reference car to a maximum speed of 65 mph.

4.0 CURVING PERFORMANCE TESTS AND ANALYSIS OF RIGIDIZED ELASTO-CUSHION TRUCKS

4.1 Test Site

A 5-degree curve near Calgary at Mileage 12.4 on the Laggan Subdivision was chosen to evaluate the curving performance of the test trucks. The rail on this curve consisted of Algoma RE 132 lb., 78 ft. staggered jointed rail. The curve had an 0.5% ascending grade in the Westward direction, a superelevation of 4.5" and a corresponding equilibrium speed of 37 mph.

4.2 Instrumentation

Strain gauges were installed on a 5-degree curve to measure lateral and vertical forces at one location in the fully developed section of the curve on both the high and low rail. A wheelset angle-of-attack measuring system was located at the same location where the lateral/vertical forces were measured. Instrumentation for this test was the same as used previously, details of which can be found in Reference 2.

4.3 Test Consist and Procedure

Two series of curving tests were carried out on successive days. The test consist during both days of testing consisted of one SD40-2 loco-

motive, with three laden 100-ton bathtub coal test cars with new Heumann profile wheels as follows.

Car 1. Barber S-2 rigidized trucks (5 pin transoms) and elastomeric shear pads of 21,000 lb/in. shear stiffness.

Car 2. Barber S-2 rigidized trucks (1 pin transoms) and elastomeric shear pads of 15,000 lb/in. shear stiffness, with stops welded to the sideframes and transoms.

Car 3. Barber S-2 trucks with C-PEP which was used as the reference car.

The first test series was carried out with the test consist as described above. The second series of tests was carried out with the elastomeric shear pads on axle 3 of the modified test cars being replaced by spacers to determine how this affected truck steering.

During each series of tests, three runs were made through the test curve in each direction at approximately 25, 37 (balance speed) and 45 mph respectively. The test consist was wyed and the tests repeated for a total of 36 runs during each series of tests. The test consist was allowed to coast through the instrumented section of the curve during each test run to record the test data.

4.4 Discussion of Test Results

The curving characteristics of the test and reference car trucks are determined from the angles-of-attack of each wheelset at the three test speeds, in the unwyed and wyed configuration (Figures 6 and 7) and the level of lateral forces (Figure 8).

As illustrated in Fig. 6 and 7 the axle number always refers to the same axle of each truck whether the consist is wyed or unwyed or if the consist is traversing the test site in the eastbound or westbound direction. A positive angle-of-attack signifies axles directed away from the centre of the curve.

As previously described, the 1 pin transom between the truck sideframes did not rigidize the truck. Hence, prior to the curving tests, stops were welded to the sideframe and transom so as to effectively rigidize the truck to evaluate the concept of a rigidized elasto cushion truck.

From Fig. 6 comparing the angle-of-attack of the modified trucks (1 pin transoms) with the conventional Barber S-2 trucks, one can observe a large reduction in angles-of-attack of the lead axle as a result of wheelset steering. For the second car with modified trucks (5 pin transoms), as the truck was not maintained square when initially rigidized, the angles-of-attack of the leading axles of the truck were found to vary, depending on the direction of travel through the test curve.

The angle-of-attack results obtained during the two series tests with the modified and conventional car trucks were similar. For the second series of tests the only exception was the angles-of-attack for axle 3 of the test trucks increased when they were the leading axles. This was due to loss of self-steering when the elastomeric shear pads were replaced by spacers.

To correlate the two measured parameters, angles-of-attack and lateral forces, a sample of the data is presented in Figure 8. The sign convention for the force measurements is that positive high and low rail forces are directed away from the centre of the curve. From Fig. 8 it can be observed that there is a general trend of increasing lateral creep force on the low rail with increasing angle-of-attack. This effect has been described in earlier reports (Reference 2).

4.5 Test Results

1. Rigidizing the conventional Barber S-2 truck (1 pin transom with stops welded to rigidize the truck) and using elastomeric shear pads for wheelset steering resulted in a reduction in angles-of-attack and lateral forces during curve negotiation compared to reference conventional Barber S-2 trucks.

2. The importance of having the truck square when it is rigidized was evident from the results of the test trucks with the five pin transoms. If a truck is not held square the benefit of wheelset steering due to the elastomeric shear pads could be lost.

5.0 CONCLUSIONS

1. The 1 pin transom between the truck sideframes was ineffective in preventing truck parallelogramming. To effectively rigidize the truck and prevent parallelogramming of the truck sideframes it was necessary to weld stops to the sideframe and transom.

2. The 5 pin transom rigidized the trucks and prevented truck parallelogramming. However, during initial assembly the trucks were inadvertently not maintained square, thus negating the benefits of wheelset steering due to the elastomeric shear pads.

3. Rigidizing the conventional 100-ton Barber S-2 truck by means of a transom and utilizing elastomeric shear pads at the bearing adapter/pedestal interface is a viable method of reducing lateral curving forces and angle-of-attack in comparison to conventional trucks, provided the trucks are maintained square when initially rigidized.

4. Rigidizing a conventional Barber S-2 three-piece truck with a transom will improve its lateral stability. However, introducing elastomeric shear pads in a truck rigidized by means of a transom reduces the restraint on axle lateral and yaw motion and hence truck lateral stability.

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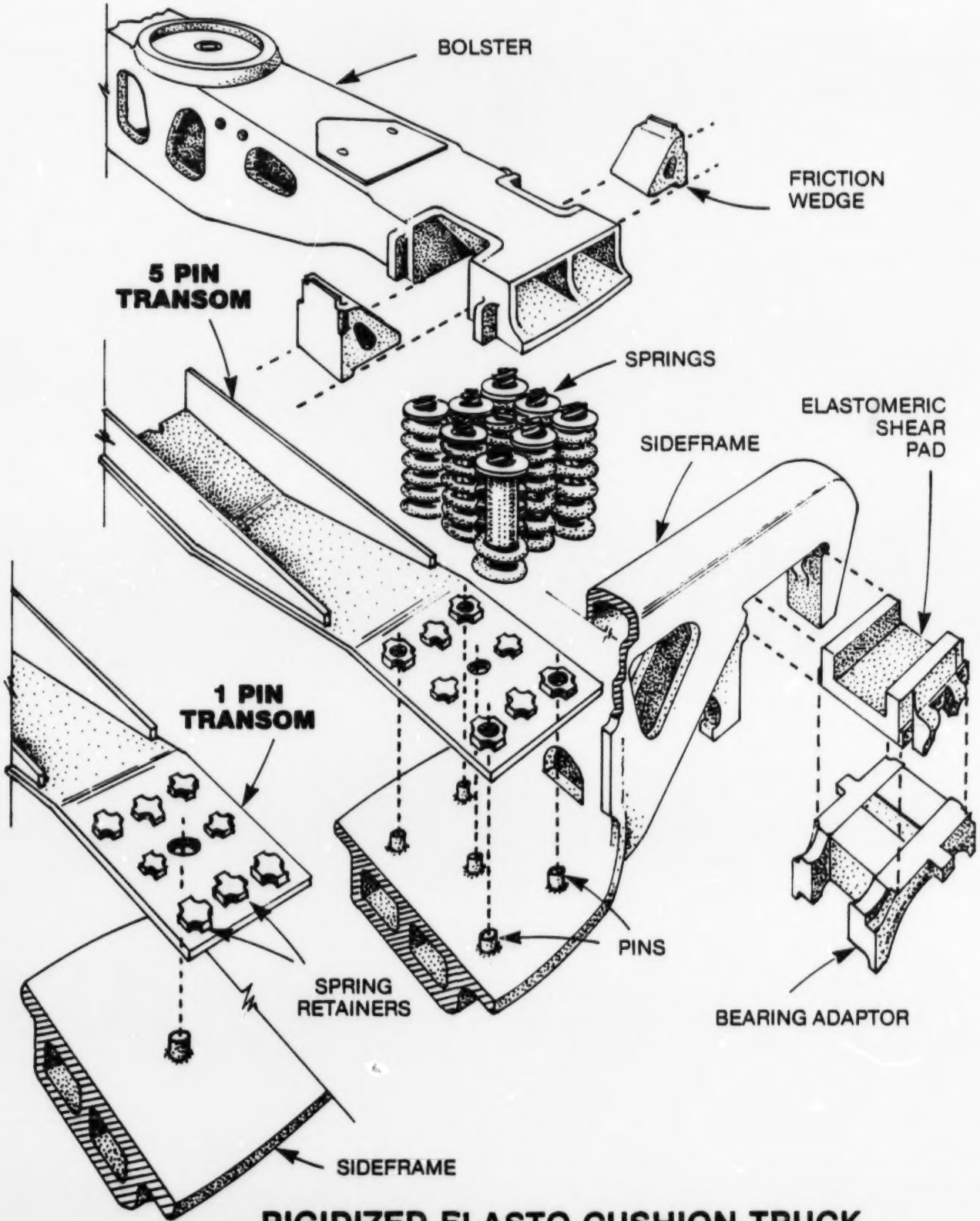
2. Railroad Dynamics Incorporated (RDI) Truck Evaluation Test 'TP 2970', Department of Research, Canadian Pacific Ltd., Report No. S670-81, March 1981. R. Gonsalves, W. Pak, G. Izbinsky.



RIGIDIZED ELASTO CUSHION TRUCK

FIGURE 1

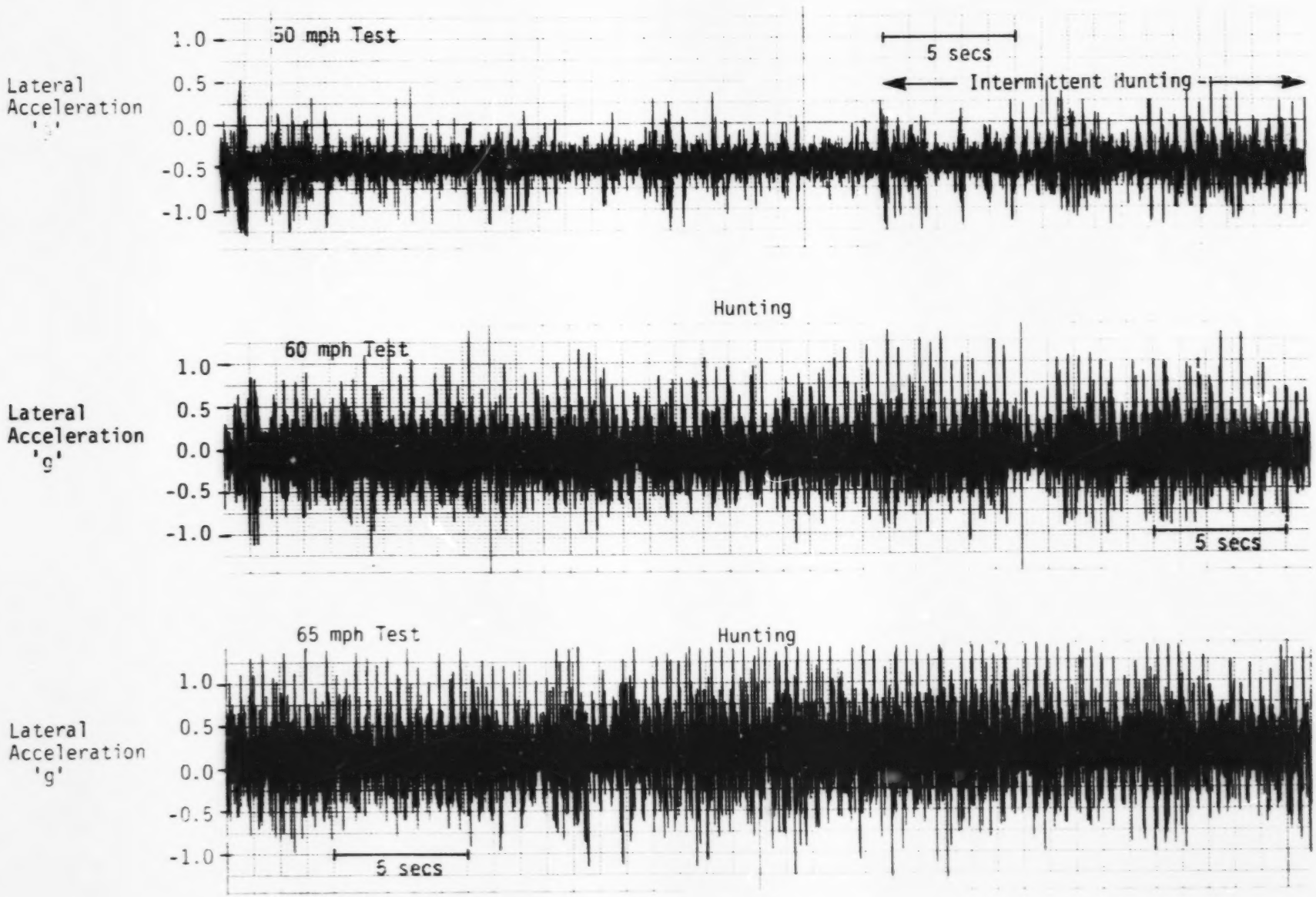


Figure 2: Illustration of accelerometer output (mounted in the lateral direction on axle bearing endcap) on Car CP 349580 with Test Trucks, service worn wheels and 15,000 lb/in. Elastometric shear pads

Note: The trucks on car CP 349580 were not held rigid (1 pin transom).

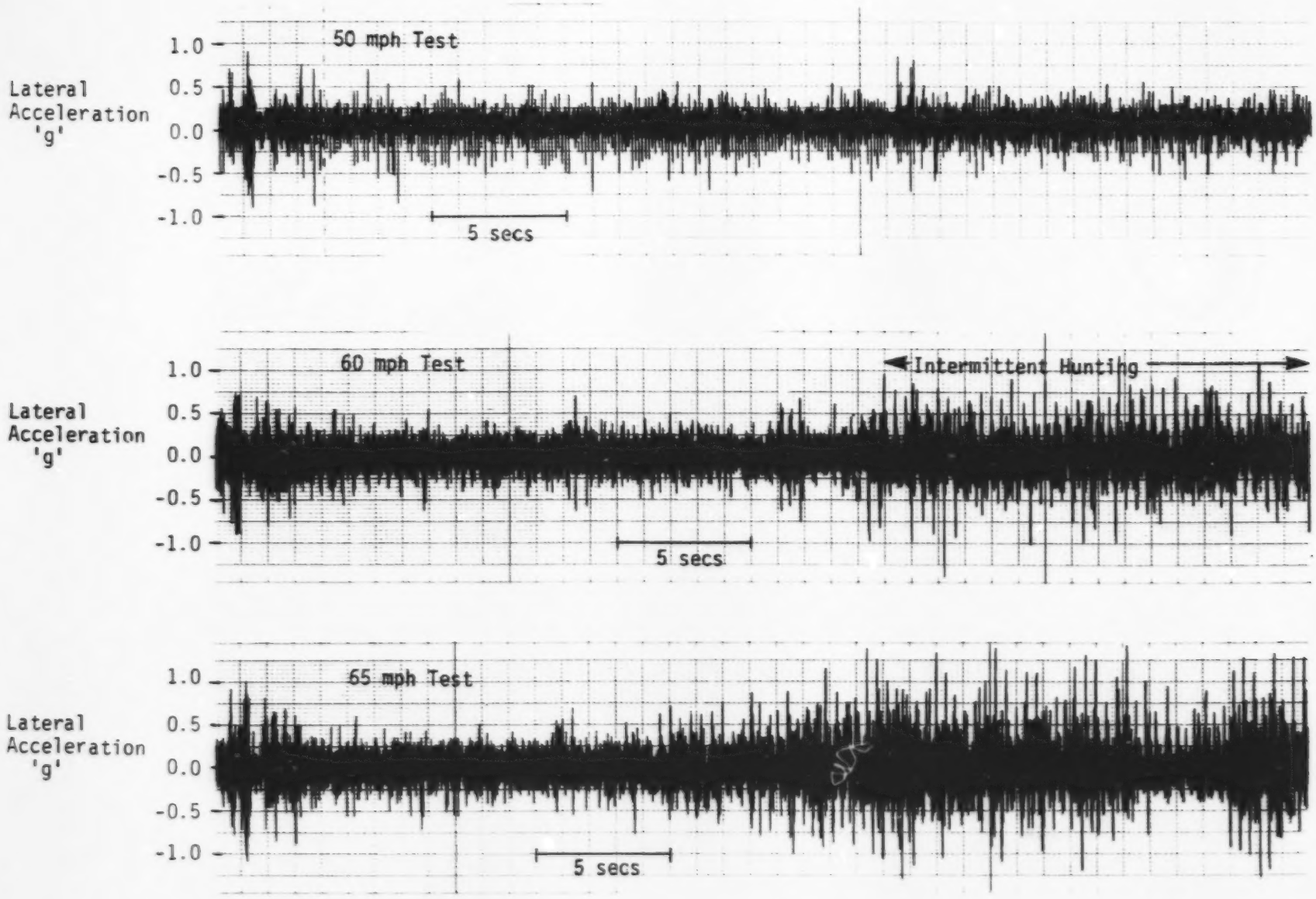


Figure 3: Illustration of accelerometer output (mounted in the lateral direction on axle bearing endcap) on Car CP 349159 with Rigidized Trucks, service worn wheels and 21,000 lb/in Elastomeric Shear Pads

Note: The trucks on car CP 349159 were held rigid (5 pin transom).

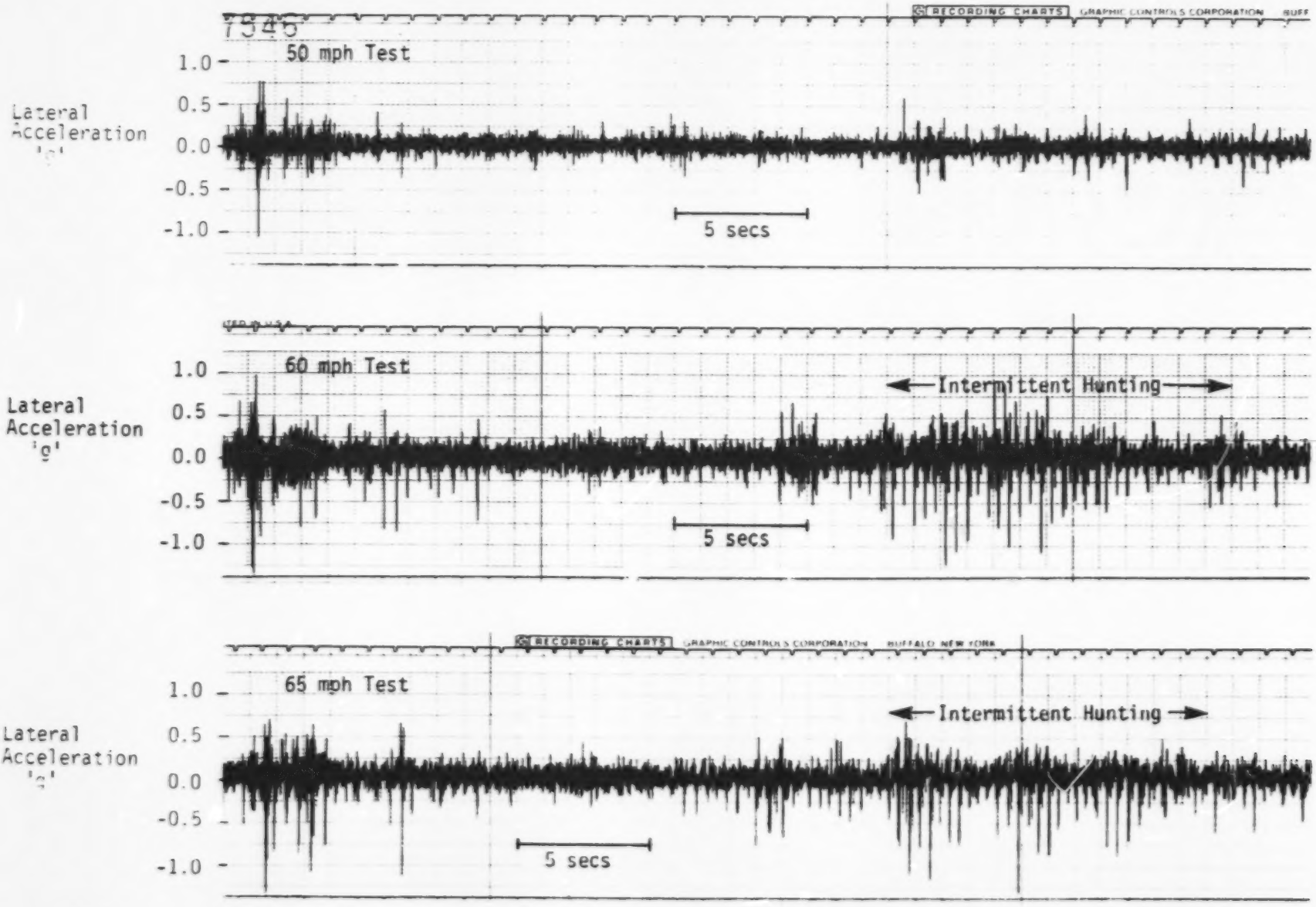


Figure 4: Illustration of accelerometer output (mounted in the lateral direction on axle bearing endcap) on Reference Car CP 351861 with service worn wheels and C-PEP

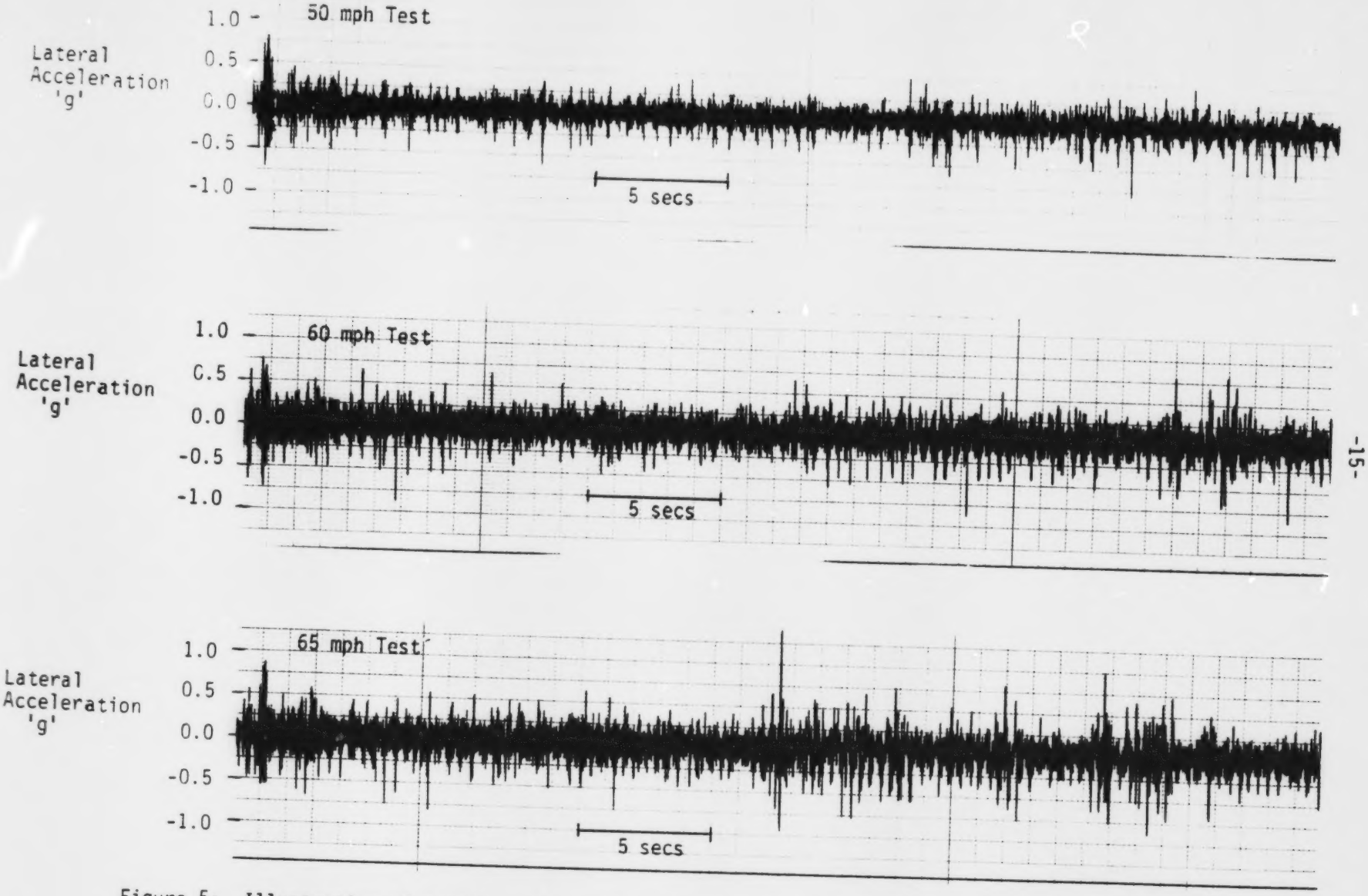


Figure 5: Illustration of accelerometer output (mounted in the lateral direction on axle bearing endcap) on Reference Car CP 351619 with new wheels and C-PEP

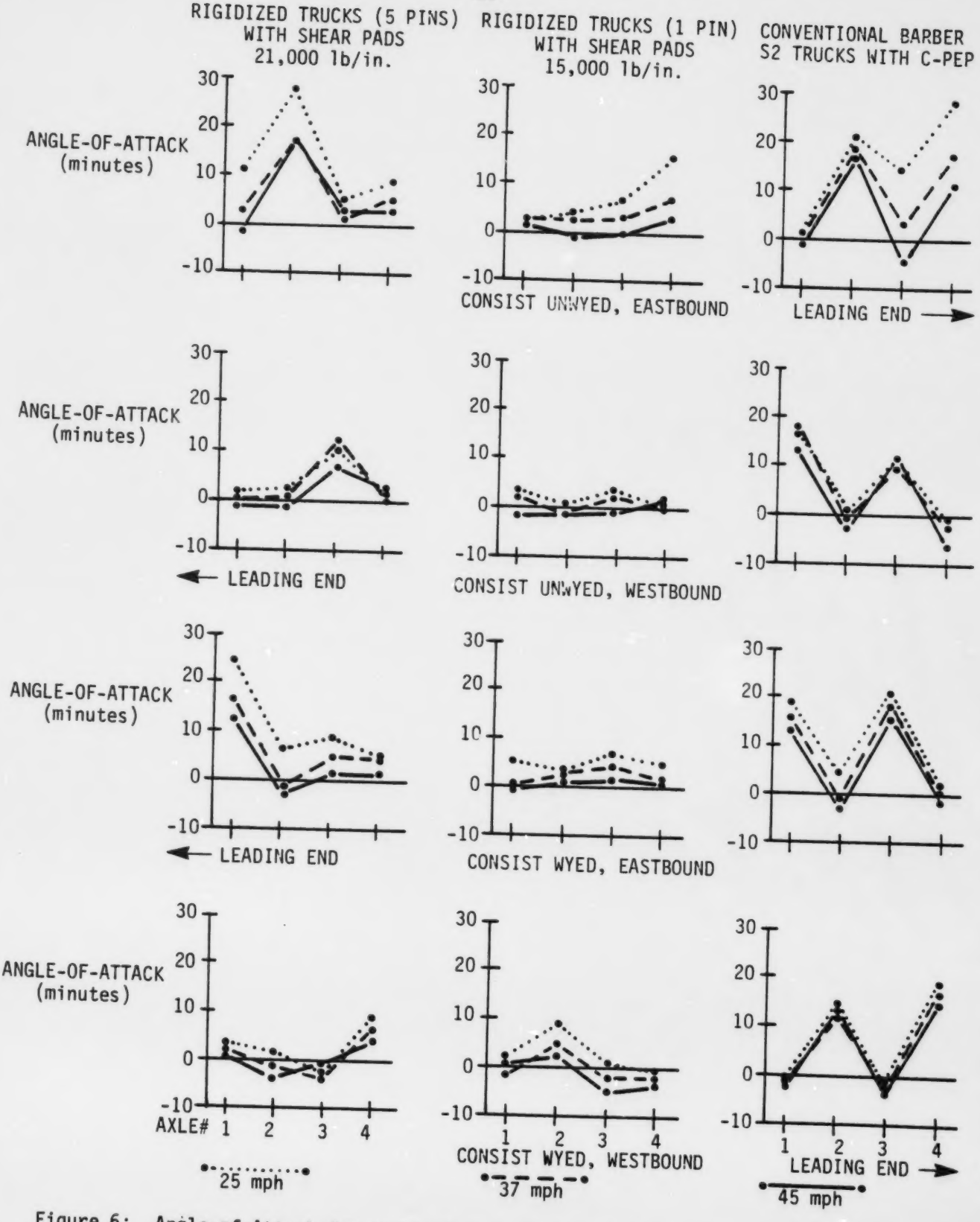
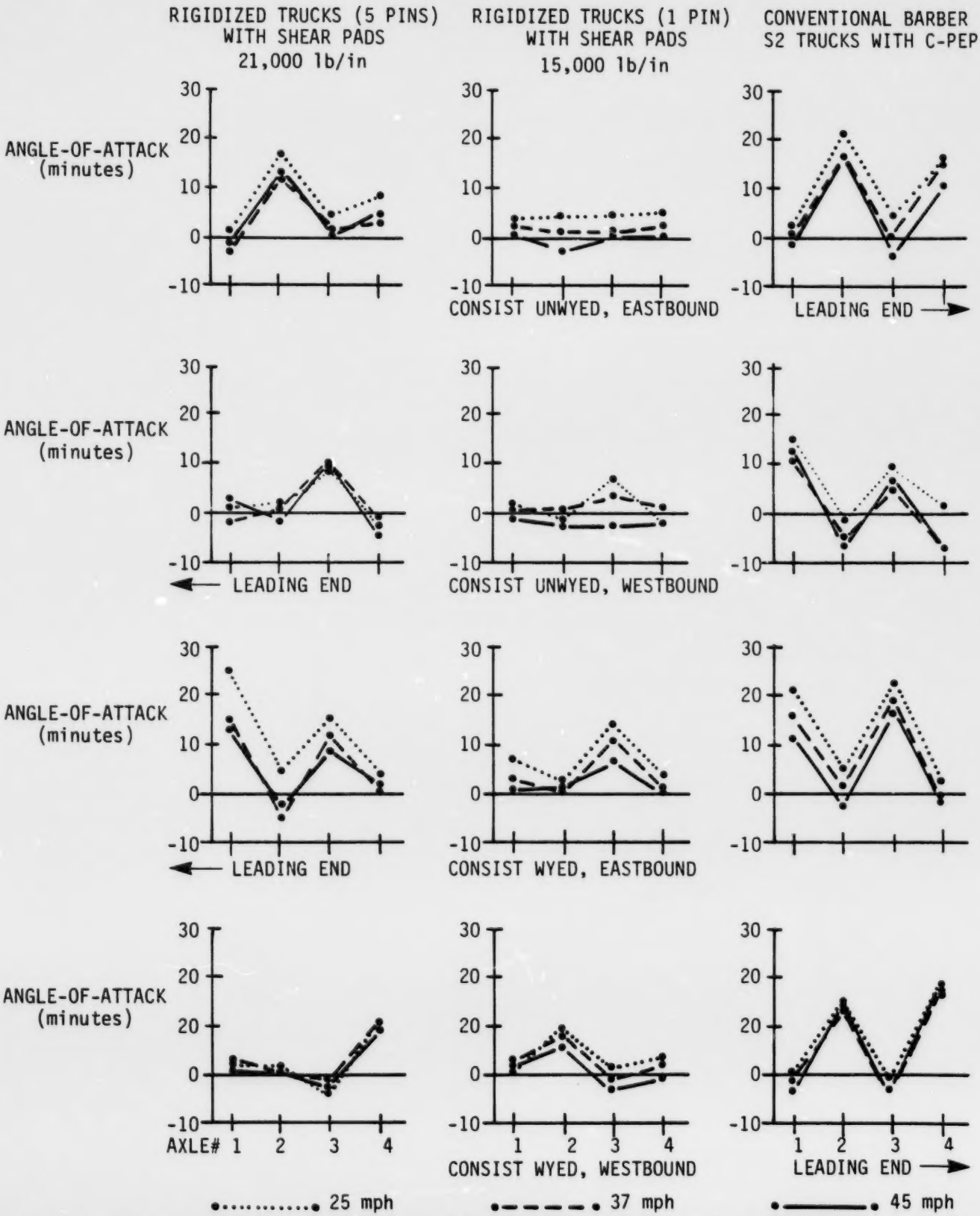


Figure 6: Angle-of-Attack for the test car trucks, at 25 mph, 37 mph and 45 mph in the unwyed and wyed position



Note: Elastomeric shear pads removed from wheelset of axle 3 & replaced with spacers.

Figure 7: Angle-of-Attack for the test car trucks, at 25 mph, 37 mph and 45 mph in the unwyed and wyed position

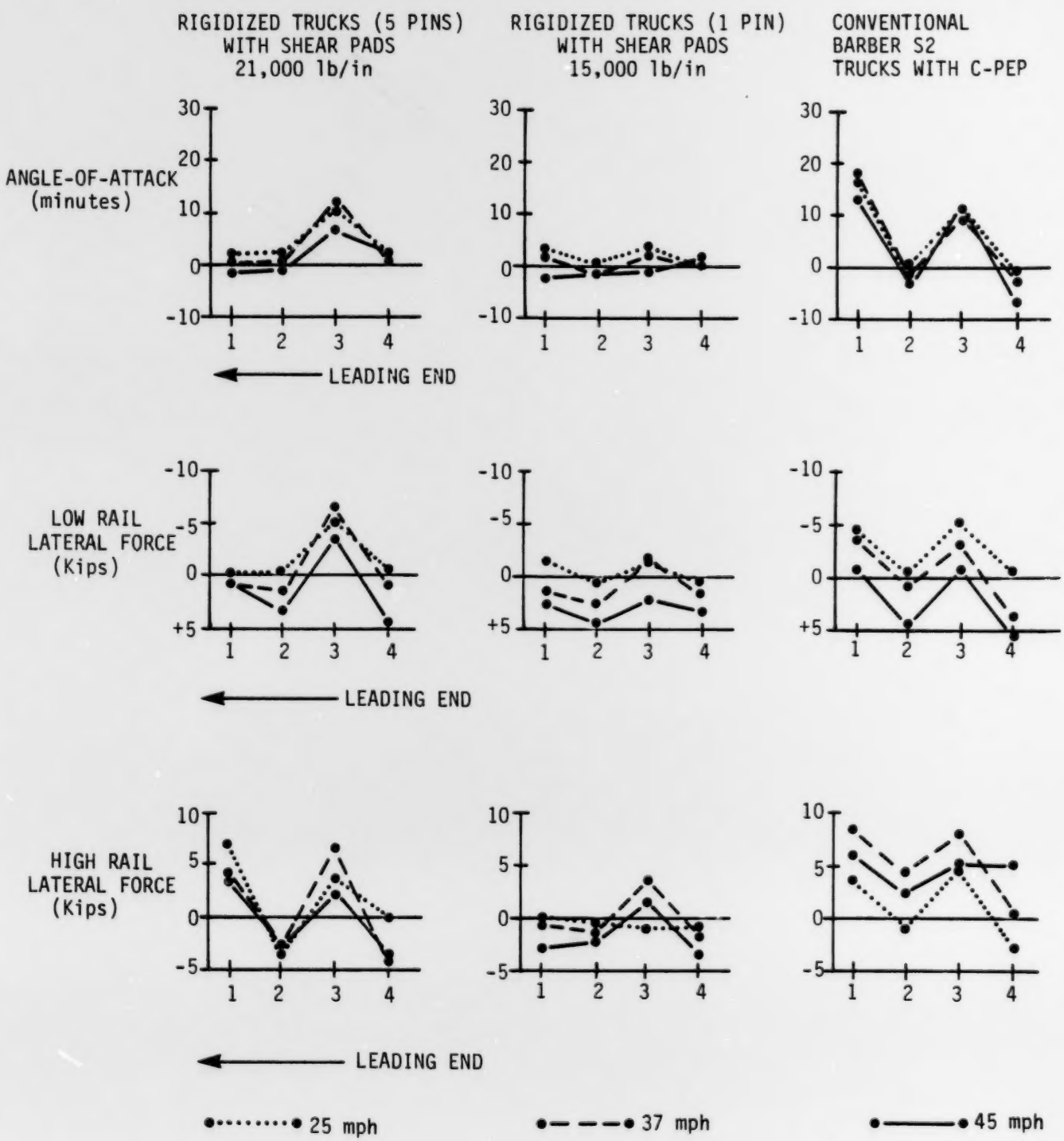


Figure 8: Angle-of-Attack and lateral forces at various curving speeds (Westbound, Unwyed)